



DEPARTMENT OF ASTRONOMY, UNIVERSITY OF VIRGINIA

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January 19, 1995

Dr. Henry Radoski
AFOSR/NP
Building 410 Room C228
Bolling Air Force Base
Washington, D. C. 20332-6448

Dear Dr. Radoski:

Enclosed please find my Final Technical and Invention Reports for grant AFOSR-89-0467 which covers the period 1 November 1993 - 30 September 1994. I also enclose a copy of the invention report covering the period 1 November 1992 - 31 October 1993.

Thank you for your attention.

Sincerely,

Trinh X. Thuan

Trinh X. Thuan
Professor of Astronomy

Enclosure

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TECHNICAL REPORT FOR GRANT AFOSR 89-0467

1 November 1993 - 30 September 1994

The Contribution of Nearby Galaxies to the Infrared Background

Personnel

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Research Highlights

1) 10 micro sub-arcsecond imaging of the blue compact dwarf galaxy Henize 2-10 (publications 9 and 11)

We have observed the Blue Compact Dwarf (BCD) galaxy He 2-10 in the mid-infrared (MIR) window using broadband filters centered at 10.5 microns and 11.8 microns. In both filters only the galaxy's central regions are detected. An extranuclear UV emitting region is not detected, implying an older age. The central regions contain two resolved components which have the same MIR properties but different H-alpha fluxes. We interpret these properties in terms of differing star forming histories. We also present a new measurement of the HI content of He 2-10 which, combined to the MIR information, show that the interstellar medium properties of He 2-10 are typical of that of BCDs. We study the energy sources for the MIR to FIR emission and show that the MIR emission is unambiguously associated with the young massive stars, but that the FIR emission requires in addition the heating contribution from a slightly more evolved stellar population.

2) The primordial helium abundance from a new sample of metal-deficient blue compact galaxies (publication 3)

We use high-quality spectrophotometric observations of 10 low-metallicity blue compact galaxies (BCGs) with oxygen abundance ranging from $12 + \log(\text{O}/\text{H}) = 7.37$ to 8.04 to determine the primordial helium abundance. We take special care into investigating the physical effects which may affect such a determination.

By taking the mean of the intercepts of both Y versus O/H and Y versus N/H linear regressions at $\text{O}/\text{H} = \text{N}/\text{H} = 0$, we determine a primordial helium mass fraction $Y_p = 0.229 \pm 0.004$, with Brocklehurst's emissivities, and $Y_p = 0.240 \pm 0.005$ with Smits's new emissivities. Taking the mean Y of the four most metal-deficient BCGs ($Z < Z_{15}$) in our sample gives $Y_p = 0.233 \pm 0.003$ with Brocklehurst's emissivities. Adding the four known BCGs with $Z < Z_{15}$ from the literature yields; $Y_p = 0.232 \pm 0.002$. These determinations are consistent with the lower limit of $Y_p = 0.236$ required by standard big bang nucleosynthesis theory. We obtain a slope $dY/dZ = 5.8 \pm 1.7$ with Brocklehurst's emissivities and $dY/dZ = 5.8 \pm 4.4$ with Smits' new emissivities, larger than the values predicted by closed-box models, but consistent with those given by chemical evolution models with differential galactic winds.

3) Hot gas outflow in the blue compact dwarf galaxy VII Zw403 (publication 4)

We have observed the Blue Compact Dwarf Galaxy VII Zw403 with the PSPC camera onboard ROSAT. We found a total X-ray luminosity of $1.94 \times 10^{38} \text{ erg s}^{-1}$

distributed in a central core to which are connected three elongated structures. We interpret this X-ray morphology as the result of a hot gas outflow from the core of the dwarf galaxy powered by the present starburst.

4) The spatial distribution of blue compact galaxies in the Second Byurakan Survey (publication 5)

We present the results of a study of the spatial distribution relative to bright normal galaxies of a new large sample of Blue Compact Galaxies (BCGs) in the zone of the Second Byurakan Survey (SBS): $7^{\text{h}}40^{\text{m}} \leq \alpha \leq 17^{\text{h}}20^{\text{m}}$, $49^{\circ} \leq \delta \leq 61^{\circ}2'$, using as statistic the distance D_{NN} to the nearest neighboring bright galaxy. We found that the majority ($\sim 80\%$) of BCGs have $D_{\text{NN}} < 5 \text{ h}^{-1} \text{ Mpc}$ and follow generally the large-scale structure delineated by bright galaxies, but that a minority ($\sim 20\%$) have $D_{\text{NN}} < 5 \text{ h}^{-1} \text{ Mpc}$ and are found in voids. The large deficiency of BCGs with $D_{\text{NN}} < 2 \text{ h}^{-1} \text{ Mpc}$ supports the hypothesis that the majority of dwarf galaxies originate as low-mass primordial density fluctuations, but not as debris resulting from tidal interactions between massive galaxies. The spatial distribution of BCGs is consistent with that found for low-surface-brightness dwarfs, supporting the idea that BCGs are LSB dwarfs undergoing intense bursts of star formation.

5) Heavy element abundances in a new sample of metal-deficient blue compact galaxies (publication 6)

We present high quality spectrophotometric observations of 15 supergiant HII regions in 14 new low-metallicity blue compact galaxies (BCGs) selected mainly from the First and Second Byurakan Surveys and with oxygen abundance $12 + \log \text{O/H}$ between 7.37 and 8.04 ($Z_{\odot}/35 \leq Z \leq Z_{\odot}/7$). We use the data to determine abundances for the elements N, O, Ne, S, Ar and for the first time in BCGs, Fe, discuss their origin and constrain current nucleosynthesis stellar models.

The main result of the present study is that none of the heavy element-to-oxygen abundance ratios studied here (N/O, Ne/O, S/O, Ar/O, Fe/O) depends on oxygen abundance. We conclude that all these heavy elements have a primary origin and are produced by the same massive ($M \geq 10M_{\odot}$) stars. The dispersion of the N/O ratio is found to be remarkably small, being only ± 0.08 in the log. This can only be understood if primary N is produced in massive stars, not in intermediate-mass ($4M_{\odot} \leq M \leq 9M_{\odot}$) stars as commonly thought. BCGs show the same O/Fe overabundance with respect to the Sun (~ 0.34 in the log) as galactic halo stars, suggesting the same chemical enrichment history, and supporting the scenario of an early enrichment of the galactic halo by massive Population III stars.

We have compared the observed heavy element abundance ratios with theoretical yields from current massive star nucleosynthesis models from Weaver & Woosley (1993). The small dispersion in the heavy element abundance ratios suggests that there is not a large IMF variation between BCGs with different metallicities.

Publications

- 1) Compact radio sources in the starburst galaxy M82 and the Σ -D relation for supernova remnants (Z. P. Huang, T. X. Thuan, R. A. Chevalier, J. J. Condon and Q. F. Yin), *Astrophysical Journal*, **424**, 114-125 (1994).
- 2) The Far-Infrared Properties of the CfA Galaxy Sample. II. Gas, Dust and Star Formation Along the Hubble Sequence (M. Sauvage and T. X. Thuan),

Astrophysical Journal, 429, 153-171 (1994).

- 3) The Primordial Helium Abundance from a New Sample of Metal-Deficient Blue Compact Galaxies (Yu. I. Izotov, T. X. Thuan and V. A. Lipovetsky), Astrophysical Journal, 435, 647-667 (1994).
- 4) Hot Gas Outflow in the Blue Compact Dwarf Galaxy VII Zw403 (P. Papaderos, K. J. Fricke, T. X. Thuan, and H. H. Loose), Astronomy and Astrophysics Letters, 291, L13-16 (1994).
- 5) The Spatial Distribution of Blue Compact Galaxies in the Second Byurakan Survey (S. A. Pustilnik, A. V. Ugryumov, V. A. Lipovetsky, T. X. Thuan and N. G. Guseva), Astrophysical Journal, April 20, 1995.
- 6) Heavy Element Abundances in a New Sample of Metal-Deficient Blue Compact Galaxies (T. X. Thuan, Yu. I. Izotov, and V. A. Lipovetsky), Astrophysical Journal, May 20, 1995.
- 7) H & K spectroscopy of luminous infrared galaxies (A. Lancon, B. Rocca-Volmerange, and T. X. Thuan), Astronomy and Astrophysics, submitted.
- 8) 10 micron Sub-Arcsecond Imaging and HI Observations of the Blue Compact Dwarf Galaxy Henize 2-10 (M. Sauvage, T. X. Thuan and P. O. Lagage), Astronomy and Astrophysics, submitted.
- 9) Studies of a New Sample of Low-Metallicity Blue Compact Galaxies (T. X. Thuan, Y. I. Izotov, V. A. Lipovetsky, and S. A. Pustilnik), in Proceedings of the ESO/OHP Workshop on Dwarf Galaxies, ed. G. Meylan (Munich: European Southern Observatory), 421-432 (1994).
- 10) 10 micron imaging of the blue compact dwarf galaxy Henize 2-10 (M. Sauvage, P. O. Lagage, and T. X. Thuan), in Proceedings of the ESO/OHP Workshop on Dwarf Galaxies, ed. G. Meylan (Munich: European Southern Observatory), 443-446 (1994).
- 11) Helium and Nitrogen Abundance in Blue Compact Galaxies with Low Metallicity (Y. I. Izotov, V. A. Lipovetsky, N. G. Guseva, A. Y. Kniazev, T. X. Thuan), in Proceedings of the ESO/OHP Workshop on Dwarf Galaxies, ed. G. Meylan (Munich: European Southern Observatory), 455-458 (1994).
- 12) Large-Scale Spatial Distribution of BCGs from New Large Samples: The Byurakan and Case Surveys (S. A. Pustilnik, A. V. Ugryumov, V. A. Lipovetsky, T. X. Thuan and J. J. Salzer), in Proceedings of the ESO/OHP Workshop on Dwarf Galaxies, ed. G. Meylan (Munich: European Southern Observatory), 133-136 (1994).

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There were twelve publications in the final with the emphasis on the study of blue compact galaxies. The blue compact dwarf galaxy He 2-10 has been observed in the mid-IR. The central regions contained two resolved components which have the same mid-IR properties but different H-alpha fluxes. The energy sources for the mid-IR to far-IR emission were studied and showed that the mid-IR emission unambiguously is associated with the young massive stars, but that the far-IR emissions requires the heating contribution from a slightly more evolved stellar population. The primordial helium abundance of low-metallicity blue compact galaxies was determined with high-quality spectrophotometric observations. The results were consistent with those obtained from chemical evolution models with differential galactic winds. The hot gas outflow in the blue compact dwarf galaxy VII Zw 403 was observed. The X-ray morphology from ROSAT is interpreted as hot gas outflow from the core of the galaxy powered by the present starburst activity. The spatial distribution of blue compact galaxies in the Second Byurakan Survey were studied. The large deficiency of blue compact galaxies support the hypothesis that the majority of dwarf galaxies. High quality spectrophotometric observations of 15 supergiant HII regions in 14 new low-metallicity blue compact galaxies were made. It was concluded that all these heavy elements have a primary origin and were produced by the same massive stars.

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